Verification of ECMWF seasonal forecasts with Euro-Atlantic weather regimes

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1. BACKGROUND AND GOALS

Large-scale atmospheric circulation is often classified in a small number of recurrent and quasi-stationary states called **weather regimes**[1] (WRs). Transitions between WRs determine a large part of the intra-seasonal circulation variability.

This study aims to provide for the first time, a **monthly assessmen**t of the goodness of the ECMWF seasonal forecasting system (S4) in simulating the observed Euro-Atlantic weather regimes up to six months in advance, with the goal of providing clues on how to enhance the future versions of S4.

3.1. RESULTS: AVERAGE FREQUENCY

Figure 1 shows the simulated (top) and observed (center) average frequency of occurrence (in %) during 1981-2015, for each lead time and target month. Bottom image illustrates the average frequency bias, e.g: the difference between simulated (top) and observed (center) average frequency.

A previous work[3] demonstrated that S4 is still not able to skillfully reproduce the observed interannual time series of the frequency of occurrence of the WRs beyond the first lead time. However, **S4 is quite able to simulate the average frequency of occurrence** during 1981-2015, for the majority of lead times and target months, as shown in figure1 (bottom).

The majority of the bias, in fact, is limited to ± 5% (with respect to an observed frequency of ~25% for each WR). **NAO+ has a positive bias during MJJ** (red points) and a negative one during the other months. **NAO- positive bias is mainly during MAM**. **BL has a mainly positive bias**, particularly in March and October. Finally, AR has a strong and positive bias in many months, particularly in August and December. Overall, forecasts often **underestimate** observations for NAO+ and NAO- and **overestimate** observations for BL and AR.

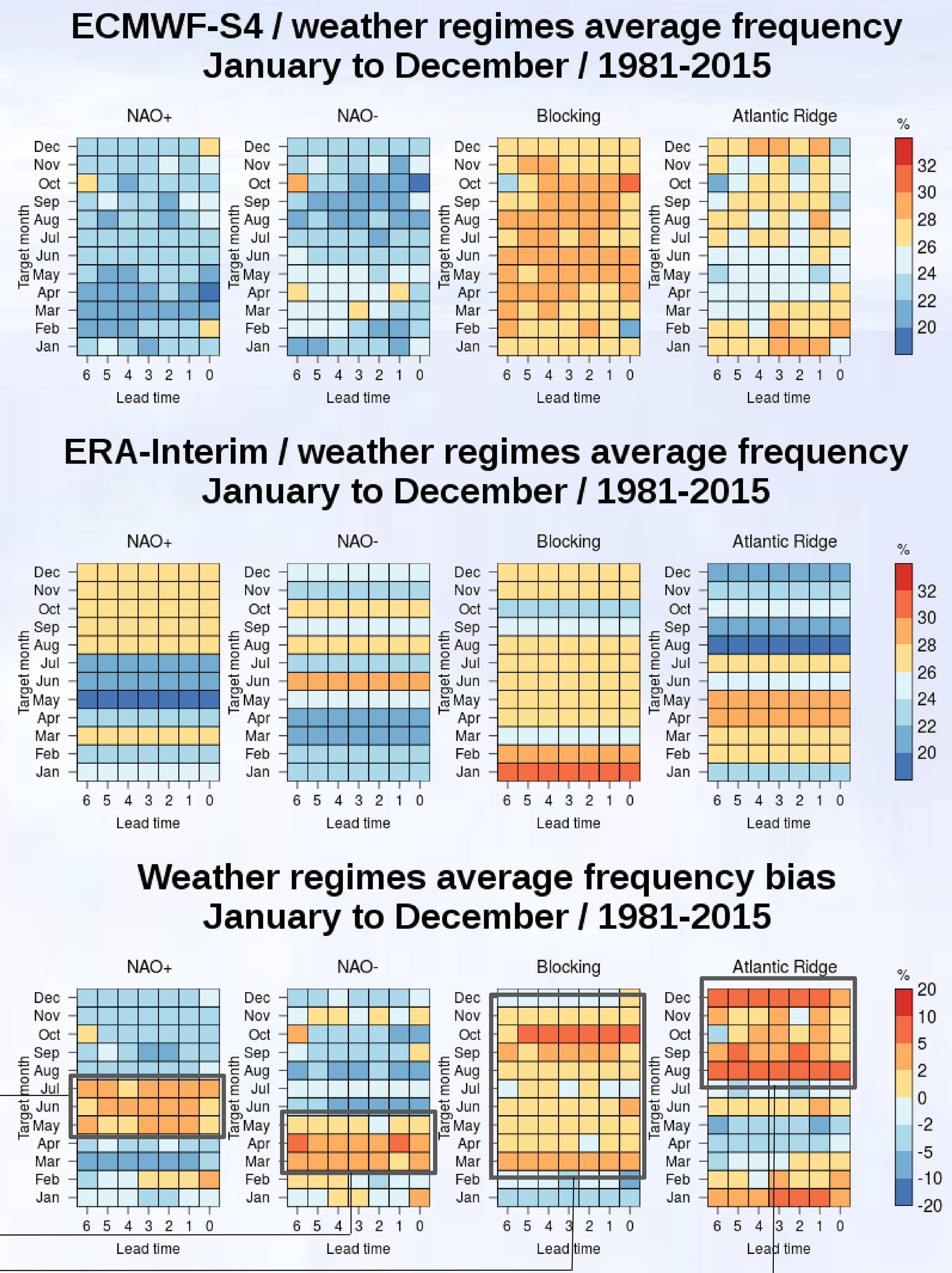

Figure 1. Simulated (*top*) and observed (*center*) average monthly frequencies of occurrence during 1981-2015 and their difference (*bottom*) for each WR, lead time and target month.

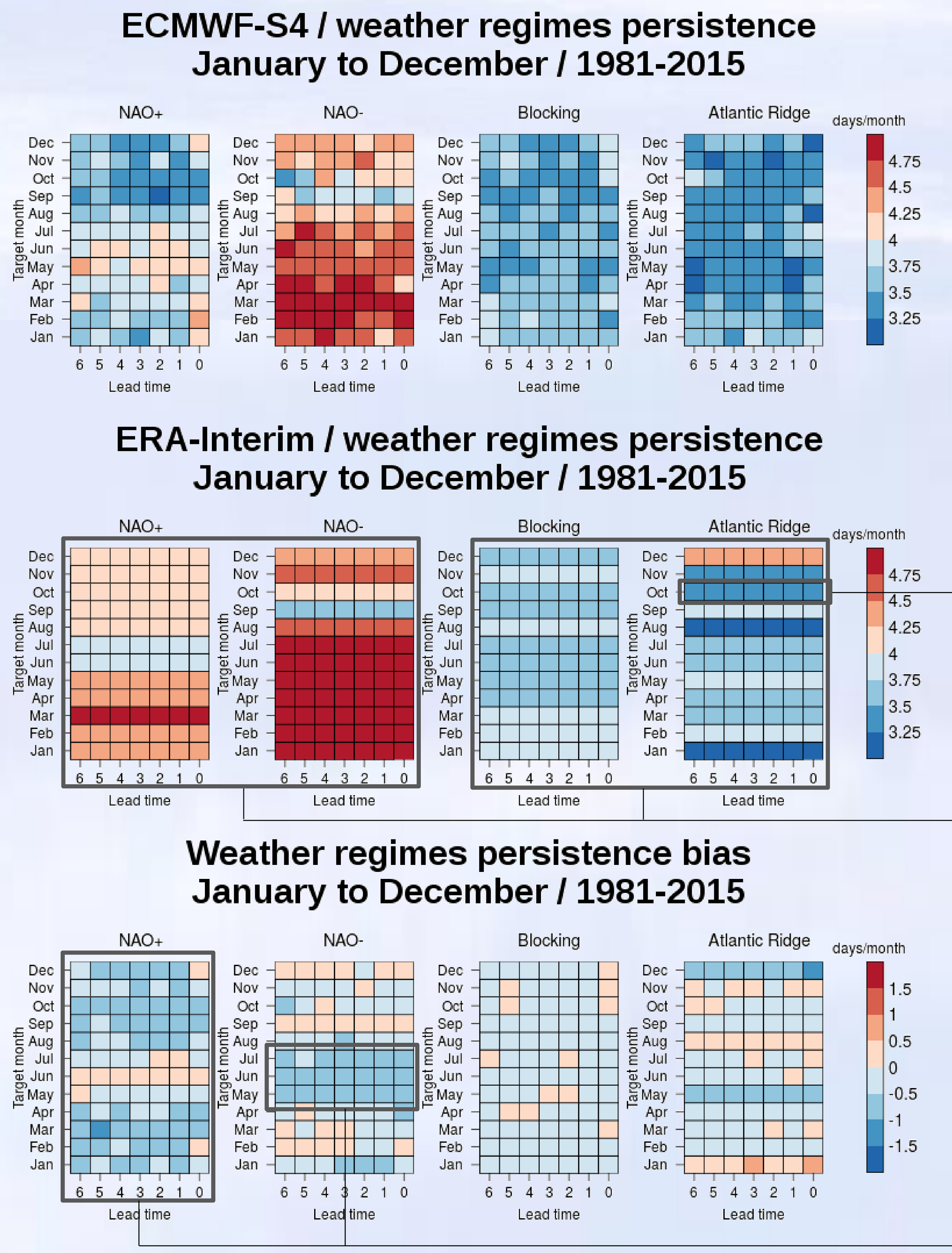

Figure 2. Simulated (*top*) and observed (*center*) monthly persistence and its bias (*bottom*) during 1981-2015 for each WR, lead time and target month.

2. DATA AND METHODOLOGY

S4 has **15 members** during hindcast period 1981-2015 and a spatial resolution of 0.75°. S4 daily-means of SLP were extracted for the Euro-Atlantic region (27°N–81°N, 85.5°W–45°E).

WRs were classified, for each individual lead time and target month, with the **k-means cluster algorithm** applied to the daily anomalies previously filtered with a LOESS polynomial regression[2].

In the Euro-Atlantic region, four clusters are retained, which often correspond to the NAO positive (**NAO+**), NAO negative (**NAO-**), blocking (**BL**) and Atlantic ridge (**AR**) WRs.

Notice that the central images of each figure always display the same values horizontally, since reanalysis don't have lead times.

3.2. RESULTS: PERSISTENCE

Persistence is the measure of the mean number of days before a WR is replaced by a new one; it is typically equal to 3-5 days (figure 2, center). Observed **NAO+ and NAO- have a higher persistence than BL and AR** (~1 day more), particularly NAO-.

The difference between simulated and observed persistence (in days/month) is plotted in the bottom part of figure 2. **Forecasts of NAO+ and NAO- tend to slightly underestimate persistence** (blue points), up to -1 days/month, **particularly NAO+.** On the contrary, BL and AR don't show any systematic error greater than ±0.5 days/month, except AR in May and December.

Overall, persistence is a main WR property that is **well reproduced by S4**.

3.3. RESULTS: TRANSITION PROBABILITIES

Figure 3 illustrates the S4-simulated and the observed transition probability (the % of times a WR shifts to another one) for each WR, and its bias (S4 minus ERA-Interim).

Both **NAO+ and NAO- have a very low simulated probability** (<10%) **of transitioning to NAO- and NAO+**, respectively.

However, the observed probability is 3-4 times higher from August to December (30-40%). Such a difference is responsible of the **large negative bias** measured in these months (-20% or more).

Generally, in other months both positive and negative biases are limited to ±10%, with a few exceptions, such as the **high bias in the transitions from NAO+ to AR in September.**

Overall, preferred NAO+ transition is to AR (40-60%), while preferred NAO- transition is to BL (40-60%), and preferred BL transition is to NAO+ (30-50%). AR does not shift to a preferred WR, as probabilities are roughly equal for each of the other three WRs.

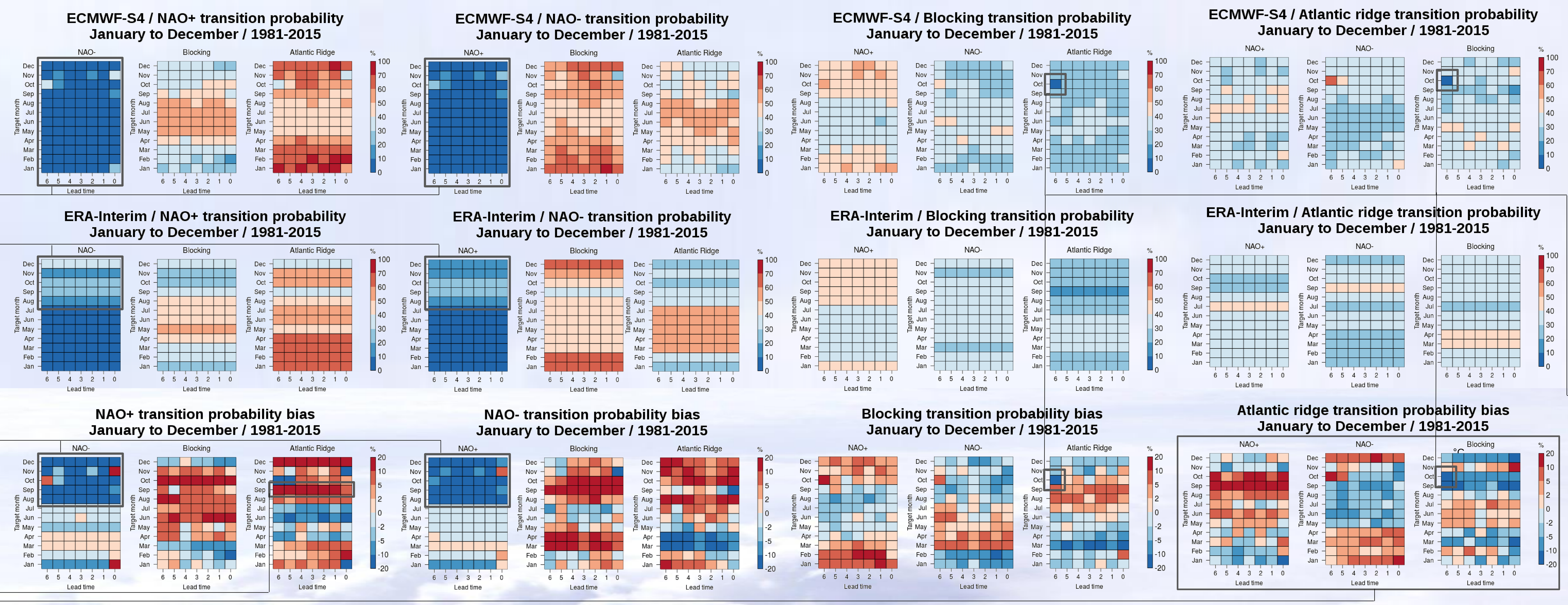

Figure 3. Simulated (*top*) and observed (*center*) probability (%) for a given WR to transition to one of the other three WRs (listed below each title) during 1981-2015 and their bias (*bottom*) for each lead time and target month. For example, simulated probability of NAO+ to shift to NAO- in December is <10% for all lead times (top left blue points), while the observed probability is 30-40%.

4. CONCLUSIONS

While it is already well known that S4 reproduces the average frequency of occurrence of the Euro-Atlantic WRs and their persistence during winter and summer[1], this is the first time that it has been demonstrated at monthly time scale and outside the winter period.

Overall, S4 tends to slightly **overestimate the average frequency of BL** (up to +10% more) and to **underestimate NAO+ persistence** (up to 1 day less).

Transition probabilities are quite well simulated by S4 (with a bias up to ±10%), with some exceptions, like the negative bias in the transition from NAO+ to NAO- and viceversa, or from BL to AR (and viceversa) in October and for high lead times (6 months). In this last case, S4 never simulate any transition, even if the observed transition probability is small but not null (~30%).

All results are also available online at:

http://www.bsc.es/ESS/ecmwf-s4-assessment-monthly-weather-regimes-against-era-interim

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